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Enhancing sustainable performance through circular economy: The mediating roles of green supply chain and process innovation

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This study examines the relationships between circular economy capability, green supply chain, green process innovation, and sustainable performance in the manufacturing sector of Saudi Arabia. As the country transitions toward its Vision 2030 goals, which emphasize sustainability and economic diversification, the manufacturing sector plays a critical role in adopting circular economy principles and green practices to reduce environmental impact and enhance resource efficiency. Using a cross-sectional research design, data were collected from managerial-level employees through a structured questionnaire. Data analysis was conducted using structural equation modeling (SEM) to examine the hypothesized relationships. The findings reveal that circular economy capability significantly drives green supply chain and green process innovation, which in turn enhance sustainable performance. The study also identifies green supply chain and green process innovation as critical mediators in the relationship between circular economy capability and sustainable performance. The results highlight the importance of integrating circular economy principles with green practices to achieve sustainability goals. It provides actionable insights for organizations to enhance their sustainability efforts, such as investing in resource efficiency, adopting green supply chain practices, and fostering process innovation.

1. Introduction

In recent years, the global focus on sustainability has intensified, driven by the urgent need to address environmental degradation, resource depletion, and climate change (Sudusinghe & Seuring, 2022). Organizations worldwide are increasingly adopting sustainable practices to minimize their environmental footprint while maintaining economic growth (Le et al., 2024). Among these practices, the circular economy has emerged as a transformative approach, emphasizing the reduction, reuse, and recycling of resources to create a closed-loop system that minimizes waste and maximizes resource efficiency. This model contrasts sharply with the traditional linear economy, which follows a "take-make-dispose" approach, leading to significant environmental harm. By transitioning to a circular economy, organizations can not only reduce their environmental impact but also achieve cost savings, improve resource efficiency, and enhance long-term competitiveness (Yin et al., 2023). In parallel, green supply chain management and green process innovation have gained prominence as critical strategies for integrating environmental considerations into business operations. Green supply chain practices, such as selecting eco-friendly suppliers, engaging in eco-design, and requiring environmental certifications, help organizations reduce their environmental footprint across the entire supply chain (Martínez-Falcó et al., 2024). Similarly, green process innovation focuses on redesigning production processes to minimize resource consumption, waste generation, and emissions, thereby contributing to sustainable performance (Abdallah et al., 2024). The manufacturing sector, in particular, plays a pivotal role in this transition, as it is one of the largest contributors to resource consumption, waste generation, and environmental pollution (Edwin Cheng et al., 2022). Manufacturing activities often involve high levels of energy use, raw material extraction, and waste production, making the sector a key target for sustainability initiatives (Chowdhury et al., 2022). In Saudi Arabia, the manufacturing sector is a cornerstone of the economy, contributing significantly to the country's GDP and employment.

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However, it also faces growing pressure to align with the nation's Vision 2030 goals, which prioritize sustainability, economic diversification, and environmental preservation. As Saudi Arabia seeks to reduce its reliance on oil and transition toward a more sustainable and diversified economy, the adoption of circular economy principles and green practices in the manufacturing sector has become a strategic imperative (Alshammari et al., 2024). The sector's significant environmental impact, coupled with its potential for innovation and efficiency improvements, makes it an ideal context for studying the integration of circular economy and green practices (Akinwale, 2024; Chaaben et al., 2024). By adopting these practices, Saudi manufacturers can not only reduce their environmental footprint but also enhance their global competitiveness and contribute to the nation's sustainability goals.

Despite the growing interest in circular economy and green practices, there is limited research on how these concepts interact to drive sustainable performance, particularly in the context of emerging economies like Saudi Arabia. This study aims to address this gap by examining the relationships between circular economy capability, green supply chain, green process innovation, and sustainable performance in the Saudi manufacturing sector. Specifically, it investigates how circular economy capabilities enable organizations to implement green supply chain practices and process innovations, which in turn enhance sustainable performance. By doing so, the study provides a comprehensive framework for understanding the pathways to sustainability in the manufacturing sector.

2. Literature Review

2.1 Sustainable Performance as the Ultimate Goal

Sustainable performance represents the culmination of an organization's efforts to achieve a balance between environmental preservation, social responsibility, and economic profitability (Chaaben et al., 2024). It reflects the organization's ability to create value not only for its shareholders but also for society and the environment. Sustainable performance encompasses a wide range of outcomes, including reduced environmental impact, improved resource efficiency, enhanced social well-being, and long-term financial stability (Sudusinghe & Seuring, 2022). As global awareness of environmental and social issues grows, sustainable performance has become a critical measure of organizational success. At its core, sustainable performance is about integrating sustainability into the organization's strategy, operations, and culture. It involves adopting practices that minimize environmental harm, such as reducing carbon emissions, conserving resources, and managing waste effectively (Chowdhury et al., 2022). Simultaneously, it requires addressing social responsibilities, such as ensuring fair labor practices, supporting community development, and promoting diversity and inclusion. Economically, sustainable performance focuses on achieving profitability while maintaining ethical business practices and long-term resilience (Edwin Cheng et al., 2022). Organizations that excel in sustainable performance are better positioned to navigate regulatory challenges, mitigate risks, and capitalize on emerging opportunities in the green economy.

The achievement of sustainable performance is influenced by various factors, including the adoption of green supply chain practices and green process innovation (Yin et al., 2023). Green supply chain practices, such as sustainable sourcing, eco-design, and collaboration with environmentally responsible suppliers, help organizations reduce their environmental footprint and improve resource efficiency. These practices not only contribute to environmental sustainability but also enhance operational efficiency and cost savings. Similarly, green process innovation, which involves redesigning production processes to minimize waste, reduce energy consumption, and lower emissions, plays a crucial role in improving sustainable performance. By adopting innovative technologies and practices, organizations can achieve significant environmental and economic benefits. The integration of circular economy principles further strengthens the pathway to sustainable performance. Circular economy practices, such as recycling, reusing materials, and extending product lifecycles, enable organizations to reduce waste, conserve resources, and lower costs (Le et al., 2024). When combined with green supply chain practices and green process innovation, circular economy principles create a holistic approach to sustainability that addresses environmental, social, and economic dimensions. This integrated approach not only enhances sustainable performance but also fosters innovation, competitiveness, and resilience in the face of global challenges.

Moreover, sustainable performance is increasingly becoming a key differentiator in the market. Consumers, investors, and regulators are placing greater emphasis on sustainability, driving organizations to adopt environmentally and socially responsible practices (Akinwale, 2024). Companies that demonstrate a strong commitment to sustainability often enjoy enhanced brand reputation, increased customer loyalty, and improved access to capital. Investors are increasingly prioritizing organizations with strong environmental, social, and governance (ESG) performance, recognizing that sustainable practices contribute to long-term financial stability and growth. Similarly, consumers are favoring products and services from companies that align with their values, creating a competitive advantage for organizations that prioritize sustainability.

2.2 Circular Economy Capability and Its Role in Sustainability

Circular economy capability refers to an organization's ability to adopt practices that minimize waste, maximize resource efficiency, and promote recycling and reuse (Theeraworawit et al., 2022). Unlike the traditional linear economy, which follows a "take-make-dispose" model, the circular economy emphasizes creating closed-loop systems where resources are continuously reused and recycled (Liu et al., 2018). This approach not only reduces environmental impact but also enhances operational efficiency and cost savings. Organizations with strong circular economy capabilities are better equipped to implement sustainable practices, as they prioritize resource efficiency and waste reduction (Bag & Rahman, 2023). These capabilities enable organizations to rethink their operations, from sourcing raw materials to managing waste, and align their practices with sustainability goals. The circular economy is particularly relevant in the manufacturing sector, where resource consumption and waste generation are significant. By adopting circular economy principles, manufacturers can reduce their reliance on virgin materials, lower energy consumption, and minimize waste, thereby contributing to environmental preservation. Moreover, circular economy capabilities foster innovation by encouraging organizations to develop new processes and technologies that support sustainability (Bai et al., 2020). These efforts not only enhance environmental performance but also improve competitiveness by reducing costs and meeting the growing demand for sustainable products.

Circular economy capability enables organizations to adopt green supply chain practices by promoting resource efficiency and waste reduction (Manavalan & Jayakrishna, 2019). Organizations with strong circular economy capabilities are more likely to implement sustainable sourcing, eco-design, and other green supply chain practices. Circular economy capability drives organizations to innovate their processes to align with sustainability goals (Centobelli et al., 2021). By prioritizing recycling, reuse, and resource efficiency, organizations are more likely to invest in green process innovation. Thus, the following hypotheses are put forward.

H$_1$: *Circular economy capability influences the green supply chain.*
H$_2$: *Circular economy capability influences the green process innovation.*

2.3 Green Supply Chain and Its Impact on Sustainable Performance

Green supply chain management involves integrating environmental considerations into supply chain operations, from sourcing raw materials to delivering finished products (Martínez-Falcó et al., 2024). Key practices include selecting suppliers based on environmental criteria, engaging in eco-design, and requiring environmental certifications (Han & Huo, 2020). Green supply chain practices help organizations reduce their environmental footprint, improve resource efficiency, and enhance their reputation among stakeholders. By collaborating with suppliers to adopt sustainable practices, organizations can achieve significant environmental and economic benefits. The relationship between green supply chain and sustainable performance is well-documented. Green supply chain practices reduce environmental risks, such as resource scarcity and regulatory penalties, while also improving operational efficiency (Chin et al., 2015). These practices not only enhance environmental performance but also strengthen relationships with customers and stakeholders who prioritize sustainability.

Green supply chain practices, such as sustainable sourcing and eco-design, contribute to sustainable performance by reducing environmental risks and improving resource efficiency (Yildiz Çankaya & Sezen, 2019). Organizations that adopt green supply chain practices are more likely to achieve better environmental, social, and economic outcomes (Alateeg & Al-Ayed, 2024). Green supply chain practices serve as a pathway through which circular economy capability enhances sustainable performance (Rahman et al., 2023). Organizations with strong circular economy capabilities are more likely to implement green supply chain practices, which in turn improve sustainable performance. Thus, the following hypotheses are put forward.

H$_3$: *Green supply chain influences sustainable performance.*
H$_4$: *Green supply chain mediates between circular economy capability and sustainable performance.*

2.4 Green Process Innovation and Its Contribution to Sustainability

Green process innovation refers to the redesign of production processes to minimize environmental impact, such as reducing energy consumption, lowering emissions, and recycling waste (Abdallah et al., 2024). It involves adopting new technologies and practices that align with sustainability goals. Green process innovation is critical for organizations seeking to improve their environmental performance while maintaining operational efficiency (Maziriri & Maramura, 2022). By innovating their processes, organizations can reduce their reliance on non-renewable resources, minimize waste generation, and lower their carbon footprint (Wang & Ng, 2020). The impact of green process innovation on sustainable performance is significant. Organizations that invest in green process innovation often achieve better environmental outcomes, such as reduced emissions and waste, as well as improved resource efficiency (Wang et al., 2021). Additionally, green process innovation can enhance competitiveness by reducing costs and meeting regulatory requirements. As sustainability becomes a key priority for consumers and regulators, organizations that innovate their processes to align with environmental goals are better positioned to succeed in the market.

Green process innovation contributes to sustainable performance by reducing resource consumption, minimizing waste, and lowering emissions (Cheng et al., 2023). Organizations that innovate their processes to align with environmental goals achieve better sustainability outcomes. Green process innovation serves as a pathway through which circular economy capability enhances sustainable performance (Bag et al., 2022). Organizations with strong circular economy capabilities are more likely to invest in green process innovation, which in turn improves sustainable performance. Thus, the following hypotheses are put forward.

H_5: *Green process innovation influences sustainable performance.*
H_6: *Green process innovation mediates between circular economy capability and sustainable performance.*

Fig. 1 demonstrates the research model.

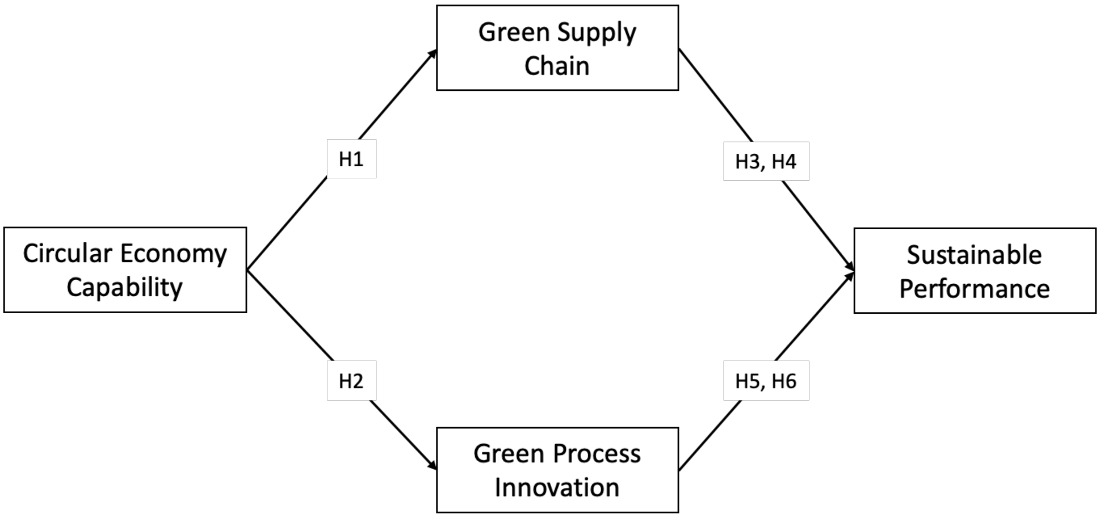

Fig. 1. Research Model

3. Methodology

This study adopted a cross-sectional research design to examine the relationships between circular economy capability, green supply chain, green process innovation, and sustainable performance. Data were collected from managerial-level employees in the manufacturing sector of Saudi Arabia. The manufacturing sector was chosen as the focus of this study due to its significant contribution to the Saudi economy and its high resource consumption, waste generation, and environmental impact. As Saudi Arabia transitions toward its Vision 2030 goals, which emphasize sustainability and economic diversification, the manufacturing sector plays a critical role in adopting circular economy principles and green practices to achieve these objectives. Managerial-level employees were selected as respondents because they possess the necessary knowledge and decision-making authority to provide accurate insights into their organizations' practices and sustainability initiatives.

The convenience sampling technique was used to collect data, which allowed for efficient and accessible data collection while ensuring a diverse representation of manufacturing firms. This sampling method was justified given the practical challenges of accessing a large number of organizations in the manufacturing sector and the need to gather timely responses. Although convenience sampling may limit generalizability, it is suitable for exploratory studies and provides valuable insights into the relationships being examined.

A structured questionnaire was developed to measure the constructs, using a 5-point Likert scale (ranging from 1 = strongly disagree to 5 = strongly agree) to record respondents' levels of agreement or disagreement with the statements. The measurement items for the constructs were adapted from established studies to ensure validity and reliability. Specifically, ten items for circular economy capability were adapted from Zeng et al. (2017), five items for green supply chain from Singh and El-Kassar (2019), five items for green process innovation from Chiou et al. (2011), and six items for sustainable performance from Lin et al. (2013).

Data analysis was performed using structural equation modeling (SEM), a robust statistical technique that allows for the simultaneous examination of multiple relationships between constructs. SEM was chosen for its ability to assess both the measurement model (validity and reliability of constructs) and the structural model (hypothesized relationships). The analysis included evaluating factor loadings, Cronbach's alpha, composite reliability, average variance extracted (AVE), and discriminant validity to ensure the robustness of the measurement model. Path coefficients and significance levels were examined to test the hypothesized relationships in the structural model.

4. Results

The demographic characteristics of the 284 participants reveal a diverse and well-represented sample (Table 1). Gender distribution shows 62% male and 38% female, reflecting a higher male representation, possibly due to the manufacturing sector's composition. Age distribution indicates that 60% of participants are between 25–44 years old, with 30% each in the 25–34 and 35–44 age groups, suggesting a focus on mid-career professionals. Education levels are high, with 52% holding a bachelor's degree and 28% a master's degree, indicating a well-educated group likely to understand and implement sustainability practices. Job positions are dominated by mid-level managers (43%) and senior managers (29%), with executives/directors and business owners each at 14%, reflecting strong managerial representation. Years of experience are evenly distributed, with 30% having 2–5 years, 25% having 6–10 years, and 25% having over 10 years, ensuring insights from various career stages.

Table 1
Demographic Characteristics of Participants (n=284)

Category	Subcategory	Frequency	Percentage
Gender	Male	176	62%
	Female	108	38%
Age	Below 25	28	10%
	25–34	85	30%
	35–44	85	30%
	45–54	54	19%
	55 and above	32	11%
Highest Education Level	High school diploma or below	28	10%
	Associate degree	28	10%
	Bachelor's degree	148	52%
	Master's degree	80	28%
Current Job Position	Mid-level manager	122	43%
	Senior manager	81	29%
	Executive/Director	41	14%
	Business owner/lead	40	14%
Years of Experience	Less than 2 years	57	20%
	2–5 years	85	30%
	6–10 years	71	25%
	More than 10 years	71	25%

Table 2 presents a measurement model that evaluates the reliability and validity of four key constructs: circular economy capability, green supply chain, green process innovation, and sustainable performance. Each construct is assessed using statistical measures such as loadings, Cronbach's alpha, composite reliability, and average variance extracted (AVE). The circular economy capability construct demonstrates strong reliability and validity. The Cronbach's alpha value of 0.841 indicates high internal consistency among the items, which is well above the acceptable threshold of 0.7. Similarly, the composite reliability of 0.855 further confirms the construct's reliability. The average variance extracted (AVE) of 0.661 suggests that 66.1% of the variance in the items is captured by the construct, which is above the recommended threshold of 0.5, indicating good convergent validity. All item loadings are above 0.7, with particularly strong loadings for items like CEC7 (0.898), CEC8 (0.87), CEC9 (0.881), and CEC10 (0.876), showing that these items are excellent indicators of the construct. The green supply chain construct also shows acceptable reliability and validity. The Cronbach's alpha value of 0.782 is above the 0.7 threshold, indicating satisfactory internal consistency. The composite reliability of 0.715 is slightly above the minimum threshold, suggesting moderate reliability. The AVE of 0.685 indicates that 68.5% of the variance in the items is captured by the construct, which is above the 0.5 threshold, demonstrating good convergent validity. Item loadings are all above 0.7, with particularly strong loadings for GSC2 (0.865), GSC3 (0.878), and GSC5 (0.872), indicating that these items are robust measures of the construct. The green process innovation construct exhibits strong reliability and validity. The Cronbach's alpha value of 0.827 indicates high internal consistency, and the composite reliability of 0.846 further confirms the construct's reliability. The AVE of 0.777 is well above the 0.5 threshold, indicating excellent convergent validity. All item loadings are above 0.7, with particularly strong loadings for GPI1 (0.889) and GPI2 (0.904), showing that these items are highly effective in measuring the construct. Finally, the sustainable performance construct demonstrates acceptable reliability and validity. The Cronbach's alpha value of 0.783 is above the 0.7 threshold, indicating satisfactory internal consistency. The composite reliability of 0.712 is slightly above the minimum threshold, suggesting moderate reliability. The AVE of 0.640 indicates that 64% of the variance in the items is captured by the construct, which is above the 0.5 threshold, demonstrating good convergent validity. Item loadings are all above 0.7, with particularly strong loadings for SP2 (0.863), SP5 (0.874), and SP6 (0.842), indicating that these items are reliable measures of the construct.

Table 3 presents the results of the discriminant validity assessment using the Fornell-Larcker criterion, which is a method to ensure that each construct in the model is distinct and measures a unique concept. Discriminant validity is established when the square root of the average variance extracted (AVE) for each construct (shown on the diagonal in bold) is greater than the correlations between that construct and all other constructs (off-diagonal values). This criterion is essential to confirm that the constructs are not overlapping and are measuring different aspects of the model. For the circular economy capability construct, the square root of the AVE is 0.863, which is greater than its correlations with the other constructs: 0.766 (green process innovation), 0.777 (green supply chain), and 0.796 (sustainable performance).

Table 2
Measurement Model

Items with constructs	Loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
Circular Economy Capability		0.841	0.855	0.661
CEC1: "Our company is devoted to reducing the unit product manual input"	0.722			
CEC2: "Our company is devoted to reducing the consumption of raw materials and energy"	0.76			
CEC3: "Our company initiatively enhances the energy efficiency of production equipment"	0.726			
CEC4: "Product packaging materials are used repeatedly"	0.851			
CEC5: "Equipment cleaning materials are used repeatedly"	0.805			
CEC6: "Leftover material is used repeatedly to manufacture other products"	0.867			
CEC7: "Waste produced in the manufacturing process is recycled"	0.898			
CEC8: "Waste products from consumers is recycled"	0.87			
CEC9: "Recycling waste and garbage is reprocessed"	0.881			
CEC10: "Waste and garbage is used after reprocessing to manufacture new products"	0.876			
Green Supply Chain		0.782	0.715	0.685
Has your company ever taken the following action with your main suppliers or subcontractors?				
GSC1: "My company selects suppliers based on environmental criteria"	0.766			
GSC2: "My company advises suppliers on environmental technical issues"	0.865			
GSC3: "My company engages suppliers in product eco-design and development"	0.878			
GSC4: "My company appraises the environmental performance of suppliers"	0.842			
GSC5: "My company requires suppliers or subcontractors to obtain third-party certification of environmental management systems such as ISO14000"	0.872			
Green Process Innovation		0.827	0.846	0.777
GPI1: "Our company consumes fewer natural resources during production"	0.889			
GPI2: "Our company engages in recycling, reusing, and remanufacturing resources"	0.904			
GPI3: "Our company focuses on using renewable technology"	0.853			
GPI4: "Our company redesigns manufacturing and logistics processes for environmental effectiveness"	0.877			
GPI5: "Our company redesigns products and services based on environmental criteria"	0.774			
Sustainable Performance		0.783	0.712	0.64
SP1: "Our company adhering to reduce paper use"	0.851			
SP2: "Our company adhering to reduce hazardous waste/scrap"	0.863			
SP3: "Our company adhering to reduce in consumption of gasoline/fuel"	0.735			
SP4: "Our company adhering to build partnership with green organizations and suppliers"	0.743			
SP5: "Our company adhering to improve of environmental compliance"	0.874			
SP6: "Our company adhering to use environmental friendly material"	0.842			

This indicates that the circular economy capability construct is distinct and does not overlap with the other constructs. Similarly, for the green process innovation construct, the square root of the AVE is 0.882, which is higher than its correlations with circular economy capability (0.766), green supply chain (0.821), and sustainable performance (0.836). This confirms that green process innovation is a unique construct in the model. The green supply chain construct also demonstrates discriminant validity, as the square root of its AVE (0.828) is greater than its correlations with circular economy capability (0.777), green process innovation (0.821), and sustainable performance (0.744). This shows that the green supply chain construct is distinct and measures a concept separate from the other constructs. Finally, for the sustainable performance construct, the square root of the AVE is 0.815, which is higher than its correlations with circular economy capability (0.796), green process innovation (0.836), and green supply chain (0.744). This confirms that sustainable performance is a distinct construct in the model.

Table 3
Discriminant Validity (Fornell-Larcker criterion)

	Circular Economy Capability	Green Process Innovation	Green Supply Chain	Sustainable Performance
Circular Economy Capability	0.863			
Green Process Innovation	0.766	0.882		
Green Supply Chain	0.777	0.821	0.828	
Sustainable Performance	0.796	0.836	0.744	0.815

Table 4 presents the path coefficients from a structural equation model, which examines the relationships between the constructs: circular economy capability, green supply chain, green process innovation, and sustainable performance. The path from circular economy capability to green supply chain has a beta value of 0.867, which is highly significant ($p < 0.001$) with a t-statistic of 24.145. This indicates a strong positive relationship between the two constructs, supporting H1. This suggests that companies with higher circular economy capabilities are more likely to implement green supply chain practices. Similarly, the path from circular economy capability to green process innovation has a beta value of 0.866, which is also highly significant ($p < 0.001$) with a t-statistic of 19.592. This supports H2, indicating that circular economy capabilities significantly enhance green process innovation efforts. The path from green supply chain to sustainable performance has a beta value of 0.535, which is significant ($p < 0.001$) with a t-statistic of 5.492. This supports H3, suggesting that implementing green supply chain practices positively contributes to sustainable performance. Additionally, the indirect path from circular economy capability to sustainable performance through green supply chain has a beta value of 0.464, which is significant ($p < 0.001$) with a t-statistic of 5.354. This supports H4, indicating that green supply chain practices mediate the relationship between circular economy capability and sustainable performance. The path from green process innovation to sustainable performance has a beta value of 0.454, which is significant ($p < 0.001$) with a t-statistic of 4.529. This supports H5, suggesting that green process innovation positively impacts sustainable performance. Furthermore, the indirect path from circular economy capability to sustainable performance through green process innovation has a beta value of 0.394, which is significant ($p < 0.001$) with a t-statistic of 4.251. This supports H6, indicating that green process innovation mediates the relationship between circular economy capability and sustainable performance. Thus, all hypotheses (H1 to H6) are supported, demonstrating significant relationships between the constructs. The findings highlight the critical role of circular economy capability in driving green supply chain and green process innovation, which in turn enhance sustainable performance. The results provide valuable insights for organizations aiming to improve their sustainability outcomes by focusing on circular economy practices and green initiatives.

Table 4
Path Coefficients

Paths	Beta	Standard deviation	T statistics	P values	Results
Circular Economy Capability → Green Supply Chain	0.867	0.036	24.145	0.00	H1 supported
Circular Economy Capability → Green Process Innovation	0.866	0.044	19.592	0.00	H2 supported
Green Supply Chain → Sustainable Performance	0.535	0.097	5.492	0.00	H3 supported
Circular Economy Capability → Green Supply Chain → Sustainable Performance	0.464	0.087	5.354	0.00	H4 supported
Green Process Innovation → Sustainable Performance	0.454	0.1	4.529	0.00	H5 supported
Circular Economy Capability → Green Process Innovation → Sustainable Performance	0.394	0.093	4.251	0.00	H6 supported

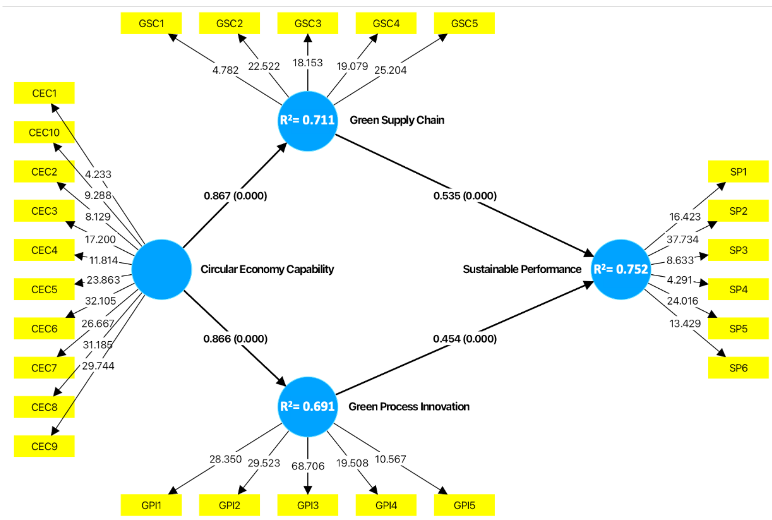

Fig. 2. Structural Model

Fig. 2 provides the R-square (R^2) values for the construct's green supply chain, green process innovation, and sustainable performance. The R-square value for green supply chain is 0.711, which means that approximately 71.1% of the variance in green supply chain practices is explained by the predictor variables in the model, such as circular economy capability. This high R-square value suggests that the model has strong explanatory power for understanding the factors influencing green supply chain practices. Similarly, the R-square value for green process innovation is 0.691, indicating that around 69.1% of the variance in green process innovation is explained by the predictor variables, such as circular economy capability. This also reflects a strong explanatory power of the model for green process innovation. The R-square value for sustainable performance is 0.752, which means that approximately 75.2% of the variance in sustainable performance is explained by the predictor variables, such as green supply chain and green process innovation. This high R-square value suggests that the model is highly effective in explaining the factors that contribute to sustainable performance.

5. Discussion

The findings of this study provide valuable insights into the relationships between circular economy capability, green supply chain, green process innovation, and sustainable performance. The results demonstrate that circular economy capability plays a pivotal role in driving green supply chain practices and green process innovation, which in turn significantly enhance sustainable performance. The study reveals that circular economy capability has a strong and direct impact on both green supply chain ($\beta = 0.867$, $p < 0.001$) and green process innovation ($\beta = 0.866$, $p < 0.001$). These findings highlight the importance of adopting circular economy principles, such as reducing resource consumption, reusing materials, and recycling waste, as a foundation for implementing green practices (Yin et al., 2023; Le et al., 2024). Organizations with robust circular economy capabilities are better positioned to integrate environmental considerations into their supply chain management and production processes. This aligns with prior research emphasizing the role of circular economy practices in fostering sustainability and resource efficiency (Chowdhury et al., 2022; Edwin Cheng et al., 2022). The study also identifies green supply chain and green process innovation as critical mediators in the relationship between circular economy capability and sustainable performance. The indirect effects of circular economy capability on sustainable performance through green supply chain ($\beta = 0.464$, $p < 0.001$) and green process innovation ($\beta = 0.394$, $p < 0.001$) are both significant. This suggests that circular economy capabilities alone are not sufficient to achieve sustainable performance; they must be complemented by green supply chain practices and process innovations (Akinwale, 2024; Chaaben et al., 2024). Selecting suppliers based on environmental criteria, engaging in eco-design, and redesigning processes for environmental effectiveness are essential steps in translating circular economy principles into tangible sustainability outcomes. The direct effects of green supply chain ($\beta = 0.535$, $p < 0.001$) and green process innovation ($\beta = 0.454$, $p < 0.001$) on sustainable performance further underscore their importance. These findings indicate that organizations can achieve significant improvements in sustainability by adopting green practices in their supply chains and production processes.

The findings of this study have significant theoretical, practical, and policy implications for organizations, researchers, and policymakers aiming to promote sustainability through circular economy practices, green supply chains, and process innovations.

From a theoretical perspective, this study contributes to the existing body of knowledge by integrating circular economy principles with green practices. It demonstrates how circular economy capabilities serve as a foundational driver for green supply chain management and green process innovation, providing a comprehensive framework for understanding sustainability in organizational contexts. The study also highlights the mediating roles of green supply chain and green process innovation, showing how these practices translate circular economy principles into tangible sustainability outcomes. This adds depth to the theoretical understanding of the mechanisms through which circular economy capabilities enhance sustainable performance (Alateeg & Alhammadi, 2024a).

From a practical standpoint, the findings offer actionable insights for organizations aiming to enhance their sustainability efforts. Companies should focus on building circular economy capabilities, such as reducing resource consumption, reusing materials, and recycling waste, as these practices form the foundation for implementing green initiatives. Organizations can invest in technologies that improve energy efficiency or redesign production processes to minimize waste (Alateeg & Alhammadi, 2024b). Additionally, the study emphasizes the importance of integrating green practices into supply chain management, such as selecting suppliers based on environmental criteria, engaging in eco-design, and requiring environmental certifications like ISO 14000. These strategies not only enhance sustainability but also improve operational efficiency and reduce costs. Furthermore, organizations should prioritize green process innovation by adopting renewable technologies, redesigning manufacturing processes, and developing environmentally friendly products. These efforts can lead to significant improvements in sustainable performance, helping organizations achieve their environmental goals while maintaining competitiveness.

The study also has important policy implications. Policymakers can use these findings to design regulations and incentives that encourage organizations to adopt circular economy practices and green initiatives. For example, governments can provide tax incentives or subsidies for companies that invest in energy-efficient technologies, waste reduction programs, or renewable energy sources. Policymakers can also promote collaboration between businesses, suppliers, and research institutions to foster innovation in green practices. Additionally, the study underscores the need for stricter environmental standards and certifications, which can drive organizations to adopt sustainable practices. By creating a supportive policy environment, governments can accelerate the transition toward a circular economy and sustainable development.

6. Conclusion

This study highlights the critical role of circular economy capability in driving green supply chain and green process innovation, which ultimately enhance sustainable performance. The findings reveal strong direct and indirect relationships, supported by robust statistical measures, demonstrating that circular economy principles form the foundation for implementing green practices. Organizations with strong circular economy capabilities are better positioned to adopt green supply chain practices, such as eco-design and supplier collaboration, and innovate processes to reduce resource consumption and waste. These efforts significantly improve sustainable performance, as evidenced by the high R-square values and significant path coefficients. The study contributes theoretically by integrating circular economy principles with green practices and emphasizing the mediating roles of green supply chain and process innovation. Practically, it offers actionable strategies for organizations to enhance sustainability, such as investing in resource efficiency, adopting green certifications, and redesigning processes for environmental effectiveness. Policy implications suggest that governments should create supportive environments through incentives, regulations, and collaborations to promote circular economy practices and green initiatives. The research underscores the importance of integrating circular economy capabilities with green practices to achieve sustainability goals. Organizations that prioritize these strategies can improve environmental performance, operational efficiency, and competitiveness while contributing to long-term sustainability.

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